Are osseous artefacts a window on perishable material culture? Implications of an unusually complex bone tool from the late Pleistocene of East Timor.

O'Connor, S.[a], Roberston, G.[b] and Aplin, K. P.[a*]

[a] Department of Archaeology and Natural History, College of Asia and the Pacific, Australian National University, Canberra, Australian Capital Territory 0200, Australia, sue.oconnor@anu.edu.au and ken.aplin@anu.edu.au; [b] School of Social Science, University of Queensland, Brisbane, Queensland 4072, Australia, g.robertson@uq.edu.au. * corresponding author (tel: +61 2 61252245; fax: +61 2 6257 1893).

Abstract

We report the discovery of a unusually complex and regionally unique bone artefact in a late Pleistocene archaeological assemblage (c. 35 ka) from the site of Matja Kuru 2 on the island of Timor, in Wallacea. The artefact is interpreted as the broken butt of a formerly hafted projectile point, and it preserves evidence of a complex hafting mechanism including insertion into a shaped or split shaft, a complex pattern of binding including lateral stabilization of the cordage within bilateral series of notches, and the application of mastic at several stages in the hafting process. It provides the earliest direct evidence for the use of this combination of hafting technologies in the wider region of Southeast Asia, Wallacea, Melanesia and Australasia, and is morphologically unparalleled in deposits of any age. By contrast, it bears a close morphological resemblance to certain bone artefacts from the Middle Stone Age of Africa and South Asia. Examination of ethnographic projectile technology from the region of Melanesia and Australasia shows that all of the technological elements observed in the Matja Kuru 2 artefact were in use historically in the region, including the unusual feature of bilateral notching to stabilize a hafted point. This artefact challenges the notion that complex bone-working and hafting technologies were a relatively late innovation in this part of the world. Moreover, its regional uniqueness encourages us to abandon the perception of bone artefacts as a discrete class of material culture, and to adopt a new interpretative framework in which they are treated as manifestations of a more general class of artefacts that more typically were produced on perishable raw materials including wood.

Keywords

artefact; bone; osseous; hafting; Pleistocene; Wallacea

Introduction

The analysis of artefacts made of bone and other osseous materials (e.g. antler, tusk) has lagged significantly behind the study of stone artefacts. A number of factors underlie this contrast, including the fact that osseous materials are less frequently preserved, especially in subtropical to tropical environments; that artefacts made on these materials are usually quite rare, even under favourable preservational circumstances; and that osseous artefacts often show minimal modification and thus present relatively few opportunities for classical typological analysis (for exceptions see Julien 1982, Petillon 2008). Despite these limitations, recent studies of osseous materials, especially those from European Palaeolithic assemblages, have made significant progress in several key areas. In particular, the combined use of experimental replication studies and high powered microscopy has established the precise nature of manufacturing technologies (e.g. d'Errico et al. 1984, 2003a; Knecht 1997; Pokines 1998; Zhilin 1998; Christensen and Valentin 2004; Pétillon and Ducasse 2012; Tejero et al. 2012; Tartar and White 2013) and added a new certainty to the inference of function (e.g. Pokines and Krupa 1997; Legrand and Sidéra 2007; Tartar 2012; Buc 2011);). Other significant developments are the documentation outside of Europe of regional trends in osseous manufacturing technology (e.g. for Africa: Henshilwood et al. 2001; d'Errico and Henshilwood 2007; Backwell et al. 2008; and for Southeast Asia: Barton et al. 2009; Rabbett and Piper 2012), and the application of typological and technological approaches to these previously neglected regional osseous artefact assemblages (Pasveer 2004; Barton et al. 2009).

A major theme of recent literature on osseous artefacts is the extent to which the manufacture and use of 'formal' osseous tools, including their incorporation into composite tools through hafting technologies (e.g. mastic, binding), is an exclusive characteristic of fully modern human behaviour (McBrearty and Brooks 2000; Ambrose 2001; Henshilwood and Marean 2003; Klein 2009). This purposeful and purportedly symbol-laden behaviour is contrasted with a much older pattern of 'casual' use of bones and antlers by earlier hominins. Occasional use of naturally splintered bone is documented even by the earliest hominins (Backwell and d'Errico 2001), and both bone and ivory were occasionally worked using percussion methods by Middle Pleistocene European *Homo* populations (Cassoli and Tagliacozzo 1994; Rosell et al. 2011). However, claims for the contemporaneous systematic fashioning of bone and ivory by cutting, shaving and polishing have been rejected (Villa and d'Errico 2001), despite the fact that these techniques were clearly in use at that time to fashion wooden spears (Thieme 1997).

The earliest replicated evidence for careful shaping of osseous artefacts dates from the Middle Stone Age (MSA) of Africa, dated to between 80 - 60 ka (Henshilwood et al. 2001; Henshilwood and Marean 2003; d'Errico and Henshilwood 2007). While these early African assemblages typically contain small numbers of somewhat irregularly shaped bone artefacts, they nonetheless document formalised manufacturing processes as well as the occasional hafting of a bone point into a composite tool (Henshilwood and Sealy 1997). Hafting of stone artefacts was widely practiced at this time, both in Africa (Barham 2002; Lombard 2005; Rots et al. 2011) and Europe (d'Errico et al. 2003b; Rots 2012), and mastic hafting of stone artefacts is recorded from as early as the late Middle Pleistocene of Italy (c. 160 ka; Mazza et al. 2006), presumably accomplished by a pre-*sapiens* population. One still controversial assemblage, possibly dated to c. 80 ka, comes from the Semliki Valley of Zaire (Brookes et al. 1995; Yellen et al. 1995). This assemblage contains highly sophisticated harpoon-like forms that are not only morphologically complex but also imply elaborate hafting mechanisms. While the age of these artefacts is contested on account of the lack of comparable forms in the southern African context (e.g. Henshilwood and Sealy 1997), the rare occurrence of similar artefacts from early Upper Palaeolithic sites in North Africa (Yellen 1998) upholds the possibility that complex point manufacture and hafting was part of the technological repertoire of early modern humans.

The archaeological record of osseous artefact use in Southeast Asia, Melanesia and Australia shows interesting parallels with the African record. In particular, there appears to be a similar temporal progression from early 'casual' assemblages comprising low numbers of non-standardised forms to more recent 'industries' characterised by more frequent production of more 'formalised' artefacts (Barton et al. 2009; Rabbett and Piper 2012). In the Southeast Asian context, this transition appears to begin around 15 ka and the formal artefact types are interpreted as spear barbs that increased the effectiveness of either fishing or the hunting of arboreal mammals, especially monkeys (Barton et al. 2009). By contrast, in Melanesia and Australia the more formalised osseous assemblages generally date to the mid- to late Holocene and appear to be functionally diverse, some comprising armature for fishing spears or arrows (Lampert 1966, 1971:51-55; Brockwell and Akerman 2009) but others showing evidence of use in composite artefacts used for woodworking or sewing/threading (Pasveer 2004). An exception is found in the high latitude region of Tasmania where bone artefacts of a standardized spatulate form are common in deposits dating from the last glacial maximum (c. 30 -18 ka; Webb and Allen 1990; Cosgrove 1999). These artefacts lack evidence for hafting and were most likely used for piercing animal skins to make garments, a local adaptation to conditions of extreme cold (Cosgrove 1999; Gilligan 2010: 45).

Bone artefact assemblages from the islands of Wallacea, situated between the continental landmasses of the Sunda shelf and greater Australasia (see Fig. 1), conform in most respects with the regional pattern (Glover 1986; Pasveer and Bellwood 2004). Here we report a remarkable exception from Timor Leste – a regionally unique bone artefact of strikingly complex form, from an early context (c. 35 ka). This artefact challenges the notion that complex bone-working and hafting technologies were a relatively late innovation in this part of the world. Moreover, its regional uniqueness encourages us to abandon the perception of bone artefacts as a discrete class of material culture, and to entertain a new paradigm in which they are treated as manifestations of a more general class of artefacts that more typically were produced on perishable raw materials including wood.

Theory

Every human artefact is a manifestation of one or more mental constructs, and many are the product of remarkably complex internal computations involving numerous symbolic elements, some based on 'learned' social values and others based on personal experience (Mithen 1996; Read and Van der Leeuw 2008). Even in the case of the 'casual' use of an object of pre-existing form (e.g. a naturally shaped stone, a bone fragment that resulted from marrow extraction), the act of selection is influenced by a mental construct of intended function, though it may also be influenced by far more complex sets of constructs that exclude certain materials for particular tasks (e.g. a fragment of dog or pig bone would not be appropriate for many tasks within an Islamic context). An artefact that is modified in some way prior to use, by contrast, owes its ultimate form to the intersection of numerous constructs related to appropriate raw materials and manufacturing techniques, intended functions and longevity of use, various 'stylistic' considerations of colour, shape and texture, as well as the acquired knowledge and skill base of the practitioner. In addition, the form of manufactured artefacts will be likely constrained by the physical properties of the raw material.

Bone has attracted much less attention as a raw material for artefact manufacture than either stone or wood (see Johnson 1985 for a useful review). Our purpose here is not to explore recent developments in this topic from a technical point of view (although this needs to be done) but merely to point out that bone, as a raw material, shares key properties with each of stone and wood. Cortical bone in particular can be shaped in a variety of ways. Like stone, it can be ground, or if it is thick enough, it can be flaked. Pieces of any size can also be cut, shaved, or scraped, all of which actions can also be performed on wood. In common with both stone and wood, the properties of bone can be altered by drying and/or heating. Drying makes bone less flexible and more likely to shatter under bending stresses (Evans 1973). Heating results in oxidation of the organic components of bone and when taken to extremes, causes the inorganic components to shrink and become highly brittle (Thompson et al. 2011).

Bone and stone are only partially interchangeable as raw materials. While a bone of sufficient size can be flaked, its internal structure prohibits highly controlled flaking of the kind that can be achieved with a high quality lithic material. Moreover, while bone flakes may perform better for some butchering tasks than stone flakes (Johnson 1985: 217), bone is undeniably softer than the majority of stone types that might be selected for flaking and will yield a less durable edge. At best, bone represents a second-rate material for flaking although its quality may be offset by factors of availability in some circumstances (Johnson 1985: 218). By contrast, most artefacts that can be made from wood might also be made from bone, provided one has access to a vertebrate animal with sufficiently large bones. In general, bone is harder than wood and requires more effort to produce a comparable artefact (Knecht 1997). However, the end product is generally more durable and perhaps for this reason, artefacts made from osseous materials are often ‘higher status’ than equivalent items made of wood. Examples are easy to find within Western culture, such as playing pieces of chess sets prior to the widespread use of plastic, and the handles of cutlery. In ethnographic contexts, components that are usually fashioned from wood are occasionally made from bone, apparently without altering their functional performance. Good examples are found in several kinds of aboriginal Australian composite artefacts, including spear-throwers (specifically, the peg; Davidson 1936), and tipped and barbed spears (Davidson 1934; Palter 1977). Excellent ethnographic examples are available from Melanesia; Sillitoe (1988) recorded several cases of functional equivalence between artefacts of wood or bone/teeth, used as either borers or pins. Admittedly, all of these examples involve morphologically simple artefacts that can be manufactured readily from wood or bone. However, under the same principle it is possible to imagine the infrequent manufacture from bone of a more complex class of artefact that was frequently manufactured from wood.

The Matja Kuru 2 artefact and its context

Geographic and archaeological context

The island of Timor is divided politically in two roughly equal parts—an Indonesian portion in the west (forming part of the province of Nusa Tenggara Timur) and the independent nation of Timor Leste (East Timor) in the east. It lies to the immediate north of the Australian continent and is the largest and highest of the Lesser Sunda Islands (Fig. 1). While Flores, another island in this group, was occupied by a relictual early hominid population since around 1 million years ago (Morwood 2004), Timor appears to have been newly colonised during the early wave of dispersal of modern humans around 50,000 years ago (Brumm *et al.* 2006; O'Connor 2007; O'Connor *et al.* 2011). Either by this time or shortly thereafter, several large vertebrates became extinct on Timor (Hooijer 1965, 1971), namely a proboscidean (*Stegodon timorensis)*, a large terrestrial tortoise (*Geochelone atlas)*, and a large monitor lizard (*Varanus* sp.).

Several archaeological sites excavated in East Timor since 2000 have produced evidence of occupation dating to before and through the Last Glacial Maximum (LGM) (O'Connor 2007; O'Connor *et al.* 2002, 2010, 2011). These sites are located in caverns formed in coralline limestone and all have yielded well-preserved faunal remains. In sites that are close to the steeply descending shoreline, such as Lene Hara and Jerimalai, the pre-LGM and LGM fauna is dominated by shellfish, bony fish and marine turtles (O'Connor *et al.* 2003; O'Connor and Aplin 2007; O'Connor *et al.* 2011). By contrast, the site of Matja Kuru 2 (MK2), situated about 10 km inland but close to a large lake (Ira Laloro) (Figure 1), produced abundant remains of 'giant' rats and reptiles, including freshwater turtles, from layers dating to between c. 36-30,000 cal BP (Aplin and O'Connor, unpublished data). However, the same levels also produced marine fauna including a broad range of shellfish derived from exploitation of the coastline, which would have been only slightly further from the site than it was throughout the Holocene.

Small numbers of bone artefacts are present in the majority of the East Timorese sites, including from late Pleistocene contexts. In keeping with the early assemblages described by Rabbett and Piper (2012), these are quite variable in terms of raw material, form, and methods of manufacture. Full details of these assemblages will be provided in a future contribution; however, one artefact is particularly striking and warrants separate consideration. This artefact was recovered *in situ* during excavation of MK2 Spit 43. This unit is bracketed by two radiocarbon dates falling into the interval 34,500-36,500 cal BP (Table 1). Bedrock was not reached in the 1 x 1 m test pit at MK2 and it is likely that earlier occupation deposits remain unexcavated. Dates from higher in the sequence cluster into two periods, 13,000-9,500 cal BP and >3,000 calBP; hence, it appears that the deposit accumulated episodically, with an early phase of occupation prior to 30,000 years ago, followed by a second phase of occupation in the terminal Pleistocene to early Holocene and a final phase in the mid- to late Holocene. MK2 currently has no evidence for use between ~30,000 BP and 13,000 BP, the time coinciding with the Last Glacial Maximum. However, other sites in East Timor document continued use of the island through this period.

At least one localized disturbance event related to the burial of a dog which is directly dated on the dog bone to 3,324-2,975 cal BP (2,967 +/- 50 WK10051) (Spriggs *et al.* 2003:56). However, major disturbance of the deposit can be ruled out by the presence of strong stratigraphic patterning in the archaeological faunal assemblage (O'Connor and Aplin, forthcoming) with lower levels (Spits 49-41) containing abundant freshwater turtle remains, middle levels (Spits 40-15) containing abundant rodent remains, and upper levels (Spits 14-1) containing abundant remains of larger, introduced mammals (pig and deer). The physical preservation of the MK2 bone artefact is consistent with other skeletal remains from the lower levels of the site, and this further increases our confidence that it derives from the period between 36,500 - 34,500 cal BP. Direct AMS dating would increase this confidence but the preservational state of the bone, and our unsuccessful attempts to date other bones from younger units of MK2, suggests that it is unlikely to contain sufficient organic matter to return a reliable date.

Morphological features of the artefact

The MK2 artefact was partially cleaned of adhering sediment in the field using a soft brush but was not subsequently treated, in order to preserve mastic or use residues. Small areas remain obscured by fine silty sediment and in several cases this forms partial infill for striae, thereby confirming their original status.

The artefact appears to be incomplete as the finely worked nature of most of the perimeter contrasts sharply with the ragged transverse edge across the break which retains patches of sediment, thereby confirming the break as an ancient feature (Fig. 2). Two morphological components are distinguished to facilitate description – a parallel-sided 'body section' that bears series of notches along parallel opposing margins; and a triangular and bluntly pointed 'tang'. The artefact measures 19.3 mm in length (from tip of tang to the transverse break) and is 12.4 mm in greatest width. It is tabular in form and of relatively uniform thickness, ranging from 1.4 – 1.8 mm.

The artefact is manufactured on a tabular piece of cortical bone. The outer (cortical; Fig, 2a) and inner (medullary; Fig. 2b) surfaces of the bone are distinguishable by the presence of longitudinal intra-osseous vascular canals on the latter. Both surfaces of the artefact are very flat and show intersecting longitudinal and oblique grinding striations, confirming that the tabular nature of the cortical bone fragment was purposefully accentuated. A combination of cutting and grinding was probably used to produce the 'tang' that terminates in a perpendicular-sided rather than conical point. A minimum of four v-shaped notches were cut into each margin of the vertical-sided 'body section' (Figs 2-3); the notches are in continuous series and are in approximate opposition across the body of the artefact.

The terminal portion of the tang shows a distinct rounding of the edges compared with the sharper edges elsewhere on the artefact, suggestive of contact abrasion within a haft (Fig. 2b. This portion of the tang also shows patches of gloss on edges and local high points (Fig. 3a), also indicative of contact abrasion as part of a composite artefact. Striations and grooves of various kinds are present on both the internal surface and lateral margins of the 'tang'. Those on the inner surface tend to have an oblique orientation but are quite variable in width and length (Fig. 3b). These were most likely caused by sand grains caught between the artefact and binding cordage which pulled them across the surface as it was applied and tightened . By contrast, a cross-cutting pattern of broader oblique furrows observed at one point on the lateral margin (Fig. 3c) is more likely caused by pressure applied by the cordage itself. Fine granular material is located within these furrows and is identified as remnants of mastic, using commonly applied microscopic criteria (e.g. Fullagar et al. 1996; Lombard 2005).

The lateral notches display clear rounding, especially on the artefact's inner surface (Fig 3d). Well-defined transverse striations aligned with the notches are present on the inner surface; these are also likely to have been caused by sand grains dragged across the surface during the binding process. A transverse binding of the body section to the haft makes sense in view of the opposing alignment of the notches. Small patches of mastic are present on many of the inter-notches (Fig. 3e) and one of these shows clear cracking and what appears to be an embedded but degraded starch grain (Fig 3f). No plant fibres were observed during microscopy but one degraded hair fragment was visible in a vascular groove on the inner surface (Fig. 4). Although scales are faintly visible, the hair fragment has no diagnostic features which might allow taxonomic identification. The hair may or may not be part of the original binding materials. Larger pieces of the mastic material appear dark red while thinner smears are either blackish or orange in colour. The mastic has not been identified but its general appearance and the observed cracking is consistent with a plant resin. The orange to reddish colour might conceivably be due to the addition of finely ground ochre in the mastic (c.f. Wadley et al. 2009) but this requires confirmation, as many plant resins are naturally coloured.

We regard the MK2 artefact as the butt or haft end of a projectile point formerly attached to a composite projectile, for four main reasons. Firstly, the surviving pointed end of the artefact is not conical, as would be expected of a functional penetrative point, but is square sided (in our view, to facilitate hafting of a tang). Secondly, the complex hafting process, involving a well-formed tang, a system of lateral notches to securely attach the point base to the shaft, and the use of mastic as well as binding cordage, all indicate a deliberate and extended effort to create a firm attachment between the bone artefact and a shaft. This is consistent with the findings of experimental work on osseous projectile points that suggest combined use of mastic and ligature is required to effectively bind a point to the foreshaft/shaft to reduce the likelihood of breakage to the osseous tip (Knecht 1997; Pétillon 2005). Thirdly, the presence of polish on the tang and notches indicates contact abrasion with a haft, which in turn suggests some functional use. Finally, the breakage pattern of the artefact suggests that it snapped while it was attached to a shaft and probably during use. A transverse break at the line of transition from the supported hafted part of the piece to the protruding, unsupported part is consistent with breakage on impact (e.g. Guthrie, 1983). If our inference of the binding mechanism is correct, the width of the attached shaft (or neck, if the projectile shaft itself was composite) can be taken as equal to or slightly greater than the width across the notches on the 'body section' of the artefact. With a shaft diameter of 9.5 - 10.0 mm, this was a projectile of considerable bulk and mass.

The distribution of polish, striations and mastic suggests that the bone artefact was most likely set into a groove carved into the side of a wooden shaft (Fig 5a), using a combination of strong cordage and mastic to provide extra attachment strength, and the lateral notches as a means of reducing slippage of the cordage along the margins of the point. However, given the deliberate flattening of both faces of the artefact we also posit an alternative, more complex hafting arrangement that involves placement of the point within a split shaft (Fig 5b). If this method was used, the cordage must have initially bound the bone point to one side of the shaft in order to produce striations on its inner surface, with a second layer of binding then securing the point between the two components of the shaft. Mastic would have been applied at all stages of creation of the haft and the notches would have functioned to minimize movement of the point within the haft.

A source taxon for the bone cannot be determined on gross morphological criteria and the state of preservation of the bone suggests that no DNA will be preserved. However, there are relatively few candidates, since Late Pleistocene Timor supported a very limited vertebrate fauna comprising rodents, bats and reptiles (Aplin and Helgen 2011). Certainly, none of the terrestrial mammals were of sufficient size to provide the raw material for the MK2 artefact. Larger vertebrates were present in the sea and rivers, notably dugong (*Dugong dugon*), various turtles and the Saltwater Crocodile (*Crocodylus porosus*) but all but the crocodile can be ruled out because they lack thick cortical bone of the kind used for the artefact (turtle carapace has a very different structure). As mentioned above, larger terrestrial vertebrates including a proboscidean (*Stegodon timorensis*), a giant monitor and a large land turtle were present on Timor at some time during the Pleistocene and these must be considered as possibilities, especially the *Stegodon*. However, no bones of these species have been recovered from any human occupation site in Timor and it is likely that they were extinct by the time MK2 was first occupied. In our view, the two most likely sources for the bone are human and Saltwater Crocodile. Histological examination might provide greater certainty.

Archaeological and ethnographic comparisons

The MK2 artefact appears to be unique in the context of Wallacean, Melanesian and Australian archaeology. However, it is possible to find parallels in artefacts from two contexts: 1) archaeological deposits of similar age or older, in other parts of the world; and 2) ethnographic material from the Melanesian region.

Archaeological comparisons

The closest parallel with the MK2 artefact is found within the remarkable assemblage of bone artefacts from Katanda in the Upper Semliki Valley in Zaire. At Kt9 and Kt16 a number of bone artefacts, including uniserial barbed projectiles, were found in contexts associated with a lithic assemblage described as falling "technologically and typologically within the broad range of the MSA" (Yellen et al. 1995: 554). The faunal assemblage includes mammal and fish remains, including large catfish of up to 2m in length. The barbed bone points are spatially associated with both fish and mammal remains. One of the Katanda bone points (Kt9:7B; Yellen et al. 1995: 555, Fig. 1; see also Baquedano 2007, p. 97) bears a particular resemblance to the MK2 artefact (Figure 6). Only the butt end of the Katanda artefact is preserved but this exhibits "a series of closely spaced notches" on each margin, equivalent to the MK2 artefact. Yellen et al. (1995: 554) likewise interpret the notches as a means of facilitating hafting and they conclude that this artefact, as well as the other Katanda barbed points, was fixed permanently into a shaft rather than functioning as a harpoon. Yellen (1998) describe morphologically similar artefacts from the Late Stone Age site of Ishango in Zaire, dated to between 17-21 ka (Brooks et al. 1995).

A tantalising glimpse of similar technology comes from southern India where the site of Jwalapuram Locality 9 produced what is interpreted as the butt end of a uniserial harpoon made on antler and dated by context to c. 34 ,000 cal BP (Clarkson et al. (2009: Fig. 5b). A more abundant osseous assemblage of similar age from Batadombo-lena rockshelter on Sri Lanka consists entirely of "single- and double-ended bone and antler points, commonly with abraded or polished ends" (Perrera et al. 2011: 263) but the size and form of the smaller artefacts suggests their incorporation into composite tools. Even closer to Timor, a similarly unique biserially barbed bone artefact is reported from the Solo River terraces in East Java (Van Heekeren 1972: 58-9; Fig. 2). Originally described as a ‘harpoon’ and referred to the Middle Pleistocene, the age and even the provenance of the artefact has been questioned (Bellwood 1997: 66). Recent estimates of the age of the principal fossil-bearing terrace of the Solo River vary wildly, from as little as 35-50 ka BP (Swisher et al. 1996) to as much as 546 ka BP (Indriati et al. 2011). The Jwalapuram and Solo artefacts resemble the MK2 artefact only in respect of the presence of notches which appear from the original illustration to represent barbs rather than components of a haft.

As mentioned earlier, the African MSA contains abundant evidence for hafting of projectile points including examples made from bone. To date, the documented range of hafting technologies has included the use of binding (Henshilwood and Sealy 1997) and of mastic materials (Lombard 2004; Rots et al. 2011), the latter including the addition of ochre to improve its functional properties (Lombard 2005; Wadley et al. 2009). Evidence for the use of lateral notches on points is currently restricted to the Katanda artefacts among MSA assemblages, though later occurrences of comparable technology are found in assemblages of early to mid- Holocene age from Lowasera in northern Kenya (Phillipson 1977; Yellen 1998). Outside of the category of points, morphologically similar notches produced through opposing oblique cuts are present on several bone fragments from MSA layers of Sidubu Cave (d’Errico et al. 2012: Fig. 6). Since one of these appears to represent a piece of a mammal vertebra and another, a piece of scapula, it is unlikely that they represent fragments of points. However, it is possible that the notches were created to facilitate binding for some other purpose. An alternative interpretation of these particular notched pieces is that they represent a form of tally keeping, or some other form of symbolic behaviour (D’Errico et al. 2012). The reported lack of polishing or other modification associated with use is consistent with this view, as may be the variety of different skeletal elements involved.

Bone and antler projectile points from the European Upper Palaeolithic show great diversity of hafting mechanisms including hafting mechanisms (e.g. single- and double-bevelled based points) that wedge the point base into a split-haft, as suggested for the MK2 point, as well as contrary mechanisms that insert the haft into the point (e.g. split-based points and Baguette Demi-Rondes) (Knecht 1993; Cattelain 1997; Julien 1982; Pétillon 2006). However, the use of lateral notching to facilitate binding is rare or absent in these contexts.

Ethnographic comparisons

Given the great age of the MK2 artefact and the clear evidence for its status as a hafted point, there would be little benefit to making an exhaustive survey of ethnographic sources or collections in search of a precise morphological analogue. Instead we confine our remarks here to some general comments on the frequency of use of particular components of the hafting technology in the Australasian and Melanesian regions for which there is an abundance of ethnographic material in collections worldwide, and where there are ongoing traditions of spear and arrow manufacture. Much less information is available on traditional practices in many parts of the region of Wallacea on account of early cultural dislocations following European arrival.

The bow and arrow was not employed on continental Australia at the time of European contact, despite its widespread use in Melanesia and Wallacea. Australian spears were thrown either by hand or by spear thrower (Davidson 1934, 1936). In most regions of Australia ethnographic examples are either a simple wooden shaft with or without lateral barbs, variably made of stone, bone or hardwood, and fixed in place with cordage and/or mastic (Davidson 1934; Brockwell and Ackerman 2007). However, composite spears with either a single hardwood point or multiple prongs are documented in many regions (Davidson 1934). Spears from northern Australia are possibly more variable, including diverse forms in which the barbs are carved out of the wooden shaft, and a higher proportion of composite spears, often with a separate foreshaft and a flaked stone point which is attached to a notch in the foreshaft by combinations of cordage and mastic (Davidson 1934, Ackerman et al. 1978).

In Melanesia the majority of spears and arrows are composite with at least two components, sometimes many more. There is great variety in function and often well-developed stylistic components, and this is reflected in a wide variety of morphologies in the form of the points and the nature of the hafting arrangements. The majority of points are manufactured from hardwoods, with lesser numbers produced on other materials including bamboo and bone. In a large sample of arrows from highland regions of Papua New Guinea Bush (1985) found the most common hafting mechanism to be a simple tapering butt inserted into a hollow shaft; however, alternative hafting mechanisms include a system akin to that hypothesised in Fig. 4A that Bush (1985: 267) calls ‘surface laid to surface’. All hafting styles include binding of the point to the haft with cordage of one or more kinds (strips of bamboo or orchid epidermis, or of the inner bark of certain trees), with various kinds of mastic sometimes used for additional support. Bush (1985) does not mention any examples of notching of the hafted portion of points for receipt of the cordage and our own perusal of other ethnographic sources and collections also suggests that this technique was rarely if ever employed in the hafting of arrow points. However, in the

Melanesian collection of the South Australian Museum we did locate instances of this technique in complex multi-pronged fishing spears from various localities. Aside from bearing multiple heavily barbed primary prongs, these spears sometimes feature a short bamboo point that is inset in the end of the primary shaft and thus central to the prongs. It is this central point which bears the lateral notches and is secured with cordage in precisely the fashion illustrated in Fig. 4B. The function of this short central point is evidently to impale a fish that has been surrounded and retained by the lateral prongs; the reason for the notched binding may be that this element is likely to be put under considerable strain from a struggling impaled fish and is thus in need of additional support. The function of these elements requires further investigation, especially in view of the apparent association with notched hafting.

Discussion

Consideration of the hafting mechanism

All projectile point hafting involves one or more of three basic technologies (Keeley 1982). The first is a 'jam or wedge' approach where a solid point is inserted into a hole or slot in the shaft, or in the case of a hollow point, is fitted over the end of the shaft. A point fitted in these ways is supported by mechanical forces and may not require further attachment. Binding with a tough cordage made of either animal or plant fibre can be used to supplement a jam or wedge haft or it can be used as the sole means of attachment. Binding requires the preparation of the cordage which is sometimes woven or spun from finer fibre such as hair, and often involves the use of complex knots (Sillitoe 2008; Bolton and Fyfe 2009). Mastic is a broad term to define any malleable but self-hardening substance that can be used to 'glue' the point to the haft and/or enclose it within a supporting mass. Many different kinds of mastics have been used for this purpose, including plant resins, tar and bees wax. Mastic is often prepared for use by heating and is sometimes 'improved' in functionality through the addition of various components including ochre or shredded fibre (Wadley et al. 2009).

Evidence from the MSA of Africa and the Upper Palaeolithic of Europe demonstrates that all three hafting technologies have long pedigrees, and for some, even extends back into the Middle Pleistocene. However, to our knowledge the MK2 artefact is unique among Pleistocene-age remains in demonstrating the combined application of all three technologies in one hafting procedure. Moreover, the use of lateral notching to further stabilise the haft is an unusual elaboration, albeit one that also has great pedigree, as demonstrated by the Katanda artefacts.

In ethnographic collections it is not uncommon to find similar usage of all three technologies to create a single haft. However, as noted above, the use of lateral notches to help stabilize the point is seen relatively infrequently in ethnographic contexts and in the archaeological record. The reason for this rarity is unclear as the notches would seem to improve a haft through the additional mechanical linkage between the cordage and the point. One possibility is that the notches can create weakening of the cordage though abrasion. An experimental approach might shed light on this issue.

Inference of function

Any attempt to infer the function of the MK2 artefact is obviously limited by its incomplete state. However, if the MK2 artefact was part of a functional projectile, as suggested here, then it was most likely used in the marine environment. Our principal reason for so suggesting is that none of the terrestrial game available to late Pleistocene inhabitants of East Timor would have required the use of such a hefty spear. The largest of the terrestrial mammals, the giant rats (Muridae), probably had body weights up to about 5-6 kg, but these were likely more easily clubbed or snared than speared. The next largest were various fruit bats and flying foxes (Pteropodidae), which formed a significant component of the Pleistocene diet of the occupants of the caves; a thrown spear would be relatively inefficient means of capture compared with a throwing stick or simply clubbing them within roost caves. By contrast, the marine environment around East Timor sites provided a number of the larger game animals including large fish, dugong and turtles, and there is direct evidence that turtles and large fish were regularly exploited. At each of two nearby coastal caves, Jerimalai and Lene Hara, the Pleistocene assemblages are dominated by the remains of turtles and large pelagic fish such as tuna (O'Connor et al. 2011) and there is reason to believe that some of these were acquired through the use of water craft. Spears thrown from boats would be an effective method for capture of marine turtles and dugongs, and this method is still practiced by members of indigenous communities in northern Australia. A second reason for suggesting use of the tipped spear in the marine environment is that the risk of damage to the point would be far less than if used on land, especially if the intended prey were dugongs or non-scaly fish such as tuna, catfish or sharks. We should note here that while dugong remains have not yet been recognised in any of the assemblages, it is possible that their remains either have gone unrecognised in some of the more highly fragmented assemblages or that they have been missed in the small scale excavations undertaken to date. We return to this point below.

One possible argument against marine use of the tipped projectile is that the site of MK2 is situated inland from the coast. However, as the same levels of the site that produced the bone artefact also yielded significant quantities of marine shellfish and the bones of large marine fish, there is ample evidence for frequent movements to and from the coast which lies approximately 10 km from the site over relatively easy terrain.

Sampling, simplicity and representativeness of the archaeological record

The complexity of the MK2 bone artefact contrasts with the widely known simplicity of prehistoric stone artefact assemblages from Southeast Asia through to Australia (e.g. Movius 1948: 411). As recently as 1968, the eminent prehistorian J.G.D. Clarke famously pronounced "The crude and rather colourless nature of this industry may serve to remind us that the original Australian aborigines issued from one of the most unenterprising parts of the late Pleistocene world" (Clarke 1968). While current paradigms do not entertain any relationship between technological complexity and cognitive capacity among late Pleistocene regional populations of *Homo sapiens*, there nonetheless is a persistent view that the material cultures of ancient modern humans living in this peripheral corner of the world were both less complex and less dynamic than those of contemporaneous populations in Africa and Europe (Brumm & Moore 2005). A good example is found in Klein's (2009: 716-717) recent characterisation of regional prehistoric artefact assemblages as "a loosely defined Core-Tool-and-Scraper Tradition that persisted basically unchanged until roughly 4 ka. Similar artifacts occur widely in southeast Asia in late Pleistocene and early Holocene deposits, and where they are found alone, the behavioural modernity of the makers can be questioned. However, at several Australian sites the flaked stones are accompanied by such advanced behavioural markers as formal bone artifacts".

Klein's characterisation of Australian and Melanesian lithic assemblages is not entirely correct as it ignores the evidence for the production of edge-ground and other hafted tools in sites dating from close to the time of first colonisation (eg. White 1967; Groube et al. 1986; see also Geneste *et al.* 2010). Nevertheless, it is true that evidence for the extensive production of composite tools in Australia, including either stone or bone components as projectile tips or barbs, appears to be restricted to the last 8,500 years, with a marked increase in frequency of application of these technologies after c. 4000 ybp (Attenbrow et al. 2009). Overall, Klein's characterisation appears to stand for Southeast Asia where Pleistocene lithic assemblages show few retouched forms and and lack edge-ground tools, and show little evidence to suggest hafting (Bowdler and Tan 2003). Indeed in many parts of Southeast Asia simple flake-based industries with low percentages of informal retouch continue through into the late Holocene with little evident change (O'Connor 2007; Moore et al. 2009). As Klein notes, in the absence of organic artefacts there is little to identify these assemblages as the product of 'modern' behaviour (see Balme et al. 2009 for an extended discussion of this topic).

What then to make of the MK2 artefact? In particular, how can we reconcile its individual complexity with its context of overwhelming simplicity? One obvious solution to this paradox is to posit the existence of an independent flourish of innovation in late Pleistocene on East Timor – possibly even the product of an individual 'genius' who spontaneously invented all three of the major hafting mechanisms millennia ahead of their later broad adoption in the region. Such an explanation is not entirely ludicrous – we need only remember some of the great innovative thinkers of our own culture (Leonardo da Vinci, for one). But surely it is more parsimonious to view the MK2 artefact as an example of a well-established wider phenomenon; i.e., as a local manifestation of the long-standing tradition of composite tool manufacture seen in many other population of *Homo sapiens*, in this case leading to the production of a complex osseous artefact and the application of multiple hafting technologies to achieve a specific desired result. If so, and unless we are to postulate that such behaviour has become instinctive in modern humans rather than being part of the culturally transmitted behavioural repertoire, then the apparent temporal and spatial isolation of the MK2 must be illusory. Below, we develop the argument that the 'illusion' has at least two components, one related to intensity of archaeological sampling and the other related to the intrinsic nature of osseous artefacts.

The first component of the illusion relates to the intensity of archaeological sampling in the region of Southeast Asia to Australasia. In what is arguably one of the most important conceptual papers of the last decade for regional archaeologists, Langley et al. (2011; see also O'Connor et al. 2010) argue that the apparent simplicity of assemblages from Australia and Melanesia compared with their Old World counterparts is explicable in terms of the much smaller numbers of sites and the typically much smaller volumes of sediment excavated at each site, especially from late Pleistocene levels which almost always lie at depth. When volume of excavated sediment from Pleistocene sites is taken into account, Australasian assemblages are every bit as rich in evidence of symbolic and complex behaviour as those from elsewhere in the world. We believe that the same argument could be made for both mainland and island Southeast Asia and that this contributes to the sporadic detection of osseous artefacts throughout the region. Similar artefacts simply may lie undiscovered in the ground throughout the region.

The second component concerns the intrinsic nature of osseous artefacts as a class of material culture. In the Introduction to this paper we argued that bone shares many properties with wood in terms of its physical properties, the techniques that can be used to shape it, and the functional uses to which it can be put. We also made the observation that for certain classes of artefacts wood and bone or ivory seem to be interchangeable as a raw material. We now extend this line of reasoning to suggest that the rarity of osseous artefacts in most archaeological contexts is explicable on the grounds that the class of artefact they represent was overwhelmingly manufactured from wood or other perishable material.

Our argument emerges from the intersection of a number of commonplace observations. The first is that all recent and many contemporary societies that have access to wood as a raw material make extensive use of it for the production of multitudinous kinds of artefacts, ranging from highly utilitarian (e.g. fence posts) to highly non-utilitarian (e.g. statuary). In some parts of the world, and Southeast Asia provides some very good examples, almost everything used in everyday life is manufactured from wood, with the dense and silica rich walls of bamboo culms (here included under the general term 'wood') being a particularly important and versatile raw material (Boriskovskii 1968; Hayden 1977). It is a salutary lesson indeed for an archaeologist to enter a settlement and observe virtually nothing that would preserve in the archaeological record. The second observation is that for many classes of artefacts, exemplars made from wood often seem to function quite well in comparison with other raw materials. Bamboo, for example, can be used to manufacture a very sharp knife blade (Griffin 1997; West and Louys 2009) which has the advantage over some lithic materials of producing a less brittle cutting edge but the disadvantage that it tends to blunt quickly (Bar-Yosef et al. 2012). Hardwood, in contrast, is favoured for the production of many components of composite tools on account of its durability and weight. It is particularly suited to the fashioning of projectile points, as demonstrated by the overwhelming preference among Melanesian peoples for hardwood points on their composite arrows and spears (Bush 1985), and the complex networks and large volume of trade in hardwood that occurred until recently between lowland and montane populations in New Guinea (Hughes 1977). Recent experiments comparing the efficacy of wood *versus* stone projectile heads on arrows found little difference in either accuracy or performance (Waguespack et al. 2009), leading the authors to posit that the abundance of stone points in the archaeological record might have as much to do with their value as 'social signs/symbols' (ibid: 797), an argument that they extend to bone/ivory points as well. The third observation is the sheer weight of ethnographic and contemporary examples where wood and osseous products appear to be interchangeable as raw materials, at least at a superficial level. Examples used before included both functionally specific components of composite artefacts (e.g. the peg on Australian spear throwers) and potentially more symbol-laden artefacts such as playing pieces or statues. Among the latter class of items, a lack of obvious functional distinction between a wooden and say, an ivory version of the same object does not distract us from the likely social and symbolic meaning of the difference in raw material. Not only is an ivory figure intrinsically more valuable but it may also be treated differently on account of its perceived 'permanence' and potential for passage to future generations; hence, possibly more likely to be identified as a vessel for lineage or group identity than a wooden object that may be seen as a more transient participant in the social world. Ethnographic examples of similar distinctions related to the use of bone over wood are fewer but nonetheless instructive. One excellent example is provided by Sillitoe's (2008: 149-151) description of the elaborate care taken by Wola men to retrieve bones from human corpses in order to make bone points with 'lethal qualities'; the artisan is in danger of causing his own death through sorcery if a bone fragment should penetrate his finger, and the final product is a power-laden artefact that will be handled and disposed of in very different ways to a morphologically comparable hard wood point fashioned for use on a hunting arrow. Other examples from Melanesia relate to the common incorporation of animal and tree species into a clan identity, with the result that many rules govern the way that individuals and groups interact with different plants and animals in their environment, including dictating patterns of raw material selection and ultimate artefact form. Once again, a 'raw material' may have layers of symbolic meaning that override any consideration of its mechanical properties.

Our final observation was also alluded to earlier. Unless a behaviour is genuinely 'instinctive', i.e. 'hard-wired' and thus emergent in the absence of learning (Harrnstein 1972), it must be manifest with sufficient frequency in a society to ensure opportunities for learning by at least a proportion of its members (Naiman 2004). Without these learning opportunities, skills simply disappear. For a body of complex knowledge, such as how to shape and finish a functional projectile point, and how to produce good mastic, we can reasonably anticipate that each generation would need to be presented with many opportunities for learning and the honing of the required skills. Why then do archaeologists worldwide tend to find so few examples of bone and other osseous artefacts, oftentimes at a discard rate of only one or two per century or even per thousand years? Part of the answer might be that many of these artefacts probably do not survive the various processes that cause attrition of faunal assemblages, such as scavenging by carnivores, trampling, weathering and microbial breakdown. However, we doubt that this explanation represents the whole story. Instead, in many part of the world (but especially in the sub-tropical to tropical regions), we suspect that the kinds of artefacts that were occasionally manufactured from bone and other osseous materials were far more commonly made on wood. Because the common wooden versions rarely ever survived to become part of the archaeological record, an abundant class of artefact, representing a common and culturally significant mode of behaviour, is transformed into a rare class of artefact and misinterpreted as the product of an occasional behaviour of no great cultural significance. Such arguments may of course be less relevant to parts of the world where wood and bamboo were less available as raw materials, such as much of Eurasia under glacial conditions. However, we might also note that these were not the environments in which modern *Homo sapiens* evolved, and in which behavioural 'modernity' was first achieved.

To return to the specific example of MK2, we strongly suspect that hafted points of similar size and form but manufactured out of bamboo or hardwood were in regular use by the late Pleistocene inhabitants of Timor; that they probably brought his technology with them during the initial colonisation of Timor from islands to the north or west; that the core components of this technology were derived from the much earlier hafting and point manufacturing traditions of the earliest modern humans to leave Africa, and possibly from even earlier human ancestors; and that the key elements were carried further east into Melanesia and Australia as people continued their passage into this corner of the earth. It is in this sense that we would promote the MK2 artefact as a window on the perishable past, as suggested in our title. Balme et al. (2009) alludes to similar unobserved complexity in the material culture and behavioural repertoire of early proto-Australasians as they made the difficult journey from mainland Asia through to Australia, involving multiple hazardous water crossings (also Balme 2013; Balme and O'Connor in press).

No part of our argument is particularly new or controversial; nevertheless, we believe that our emphasis is novel and that the implications for our understanding of the evolution of material culture and our own species are potentially wide-reaching. Singular or rare artefacts occurring in early modern or pre modern human contexts are often argued to be anomalous or intrusive rather than broadly informative of behaviour. We challenge archaeologists worldwide to ask similar questions about the significance of 'rare' classes of artefacts where these are made on bone, antler and ivory.

Acknowledgments

We thank Sue Lindsay of the Australian Museum's Scanning Electron Microscopy and Microanalytical Unit for assistance with initial microscopy of the MK2 artefact, and Angela Frost for preparation of the figures. Sue O'Connor acknowledges the assistance and hospitality of the many East Timorese people who allowed access to critical areas and sites, and actively participated in the field activities. The fieldwork in East Timor was funded by Discovery Grant DP0556210 to O'Connor from the Australian Research Council.

References

Akerman, K., Hartwig, M., Borchardt, D.W., 1978. Notes on the Kimberley stone-tipped spear focusing on the point hafting mechanism. Mankind 11, 486–490.

Ambrose, S.H., 2001. Paleolithic technology and human evolution. Science 291, 1748–1753.

Aplin, K.P. and Helgen, K.M., 2010. Quaternary murid rodents of Timor. Part I: New material of *Coryphomys buehleri* Schaub, 1937, and description of a second species of the genus. Bull. Am. Mus. Nat. Hist. 341, 1-80.

Attenbrow, V., Robertson, G., Hiscock, P., 2009. The changing abundance of backed artefacts in south-eastern Australia: a response to Holocene climate change? J. Archaeol. Sci. 36, 2765-2770.

Backwell, L.R., d'Errico, F., 2001. Termite gathering by Swartkrans early hominids. Proc. Natl. Acad. Sci. 98, 1358-1363.

Backwell, L., d'Errico, F., Wadley, L., 2008. Middle Stone Age bone tools from the Howiesons Poort layers, Sibudu Cave, South Africa. J. Archaeol. Sci. 35, 1566-1580.

Balme, J., Davidson, I., McDonald, J., Stern, N., Veth, P., 2009. Symbolic behaviour and the peopling of the southern arc route to Australia. Quatern. Int., 202, 59-68.

Balme, J., 2013 The maritime colonization of Australia. Quatern. Int. 285, 195.

Balme, J., O'Connor, S., in press. Early modern humans in Island Southeast Asia and Sahul: Adaptive and creative societies with simple lithic industries. In: Dennell, R, Porr, M. (Eds.), East of Africa. Southern Asia, Australia and Human Origins. Cambridge: Cambridge University Press.

Baquedano, E., 2007. El Universo Neanderthal I. Museo Arcqueologico de la Comunidad.

Bar-Yosef, O., Eren, M. I., Yuan, J., Cohen, D. J., Li, Y., 2012. Were bamboo tools made in prehistoric Southeast Asia? An experimental view from South China. Quatern. Int. 269, 9-21.

Barham, L., 2002. Backed tools in Middle Pleistocene central Africa and their evolutionary significance. J. Hum. Evol. 43, 585-603.

Barton, H., Piper, P.J., Rabett, R., Reeds, I., 2009. Composite hunting technologies from the Terminal Pleistocene and Early Holocene, Niah Cave, Borneo. J. Archaeol. Sci. 36, 1708-1714.

Bellwood, P., 1997. Prehistory of the Indo-Malaysian Archipelago (Revised ed.). University of Hawai'i Press, Honolulu.

Bolton, J., Fyfe, A., 2009. Knots, Loops & Braids: an examination of fibre craft techniques in the Upper Sepik and Central New Guinea. Available at: http://www.scribd.com/doc/19700418/Knots-Loops-Braids. Dowloaded 10/25/2012.

Boriskovskii, P.I., 1968. Vietnam in primeval times, Part I, Soviet Anthropol. Archaeol. 7, 14-32.

Bowdler, S., Tan, D., 2003. A comparison of stone industries for Southeast Asia and Australia. In: Karlstrom, A, Kallen, A (Eds.), Fishbones and Glittering Emblems: Southeast Asian Archaeology 2002. Museum of Far Eastern Antiquities, Stockholm.

Brockwell, S., Akerman, K., 2007. Bone points from the Adelaide River, Northern Territory. Aust. Aborig. Stud. 1, 83-97.

Brooks, A.S., Helgren, D.M., Cramer, J.S., Franklin, A., Hornyak, W, Keating, J.M., Klein, R.G., Rink, W.J., Schwarcz, H., Smith, J.N.L., Stewart, K., Todd, N., Verniers, J., Yellen, J.E., 1995. Dating and context of three Middle Stone Age sites with bone points in the Upper Semliki Valley, Zaire. *Science* 268, 548-553.

Brumm, A., Moore, M.W., 2005. Symbolic revolutions and the Australian archaeological record. Cambridge Archaeol. J. 15, 157-75

Brumm, A., Aziz, F., Van Den Bergh, G.D., Morwood, M.J., Moore, M.W., Kurniawan, I., D.R. Hobbs, D.R., Fullagar, R., 2006. Early stone technology on Flores and its implications for *Homo floresiensis*. Nature 44, 624-628.

Buc, N., 2011. Experimental series and use-wear in bone tools. J. Archaeol. Sci. 38, 546-557.

Bush, T., 1985. Form and decoration of arrows from the highlands of Papua New Guinea. Rec. Aust. Mus. 37, 255–293.

Cassoli, P.F., Tagliacozzo, A., 1994. Considerazioni paleontologiche, paleoecologiche e archeozoologiche sui macromammiferi e gli uccelli dei livelli del Pleistoceno Superiore del Riparo di Fumane (VR) Scavi 1988–1991. Boll. Mus. Civ. St. Nat. Verona 18, 349–445.

Cattelain, P., 1997. Hunting during the Upper Palaeolithic: bow, spearthrower or both?, In: H. Knecht (Ed.), Projectile technology, Inter-disciplinary contributions to Archaeology, Plenum press, New York, pp. 213-240.

Christensen, M., Valentin, B., 2004. Armatures de projectiles et outils: de la production à l'abandon. In: Pigeot, N. (Ed.), Les Derniers Magdaléniens d'Étiolles: Perspectives Culturelles et Paléohistoriques (l'Unité d'Habitation Q31). CNRS (Suppléments à Gallia Préhistoire, 37), Paris, pp. 107-160.

Clarkson, C., Petraglia, M., Korisettar, R., Haslam, M., Boivin, N., Crowther, A., Ditchfield, P., Fuller, D., Miracle, P., Harris, C., Connell, K., James, H., Koshy, J., 2009. The oldest and longest enduring microlithic sequence in India: 35 000 years of modern human occupation and change at the Jwalapuram Locality 9 rockshelter. Antiquity 83, 326-348.

Cosgrove, R., 1999. Forty-two degrees south: the archaeology of late Pleistocene Tasmania. J. World Prehist. 13, 357-402.

Davidson, D.S., 1934. Australian spear-traits and their derivations. J. Polynes. Soc. 43, 41-72, 143-162.

Davidson, D.S., 1936. The spearthrower in Australia. Proc. Amer. Phil. Soc. 76, 445-483.

d'Errico, F., Henshilwood, C., 2007. Additional evidence for bone technology in the southern African Middle Stone Age. J. Hum. Evol. 52, 142-163.

d'Errico, F., GIiacobini, G., Puech, P.-F., 1984. Varnish replicas. A new method for studying worked bone surfaces. Ossa, 9-10, 29-51.

d'Errico, F., Julien, M., Liolios, D., Vanhaeren, M., Baffier, D., 2003a. Many awls in our argument. Bone tool manufacture and use in the Châtelperronian and Aurignacian levels of the Grotte du Renne at Arcy-sur-Cure. In: Zilhão, J., d'Errico, F. (Eds.), The Chronology of the Aurignacian and of the Transitional Technocomplexes. Dating, Stratigraphies, Cultural Implications. Instituto Português de Arqueologia, Lisbon, pp. 247-271.

d'Errico, F., Henshilwood, C., Lawson, G., Vanhaeren, M., Tillier, A., Soressi, M., Bresson, F., Maureille, B., Nowell, A., Lakarra, J., Backwell, L., Julien, M., 2003b. Archaeological evidence for the emergence of language, symbolism, and music: an alternative multidisciplinary perspective. J. World Prehist. 17, 1-70.

d'Errico, F., Backwell, L.R., Wadley, L, 2012. Identifying regional variability in Middle Stone Age bone technology: The case of Sibudu Cave. J. Archaeol. Sci. 39, 2479-2495.

Evans, F.G., 1973. Mechanical properties of bone. Charles C. Thomas, Springfield, Illinois.

Fullagar, R., Furby, J., Hardy, B., 1996. Residues on stone artefacts: state of a scientific art. Antiquity 70, 740-745.

Geneste, J.M., David, B., Plisson, H., Clarkson, C., Delannoy, J.J., Petchey, F., Whear. R., 2010. Earliest Evidence for Ground-Edge Axes: 35,400 +/- 410 Cal Bp from Jawoyn Country, Arnhem Land. Aust. Archaeol. 71, 66-69.

Gilligan, I., 2010. The prehistoric development of clothing; archaeological implications of a thermal model. J. Archaeol. Method Theory 17, 15-80.

Glover, I., 1986. Archaeology in Eastern Timor, 1966-67. Terra Australis 11. Canberra: Australian National University.

Griffin, P.B., 1997. Technology and variation in arrow design among the Agta of northeastern Luzon. In: H. Knecht (Ed.) Projectile Technology, Plenum Press, New York, pp. 267-286.

Groube, L., Chappell, J., Muke, J., Price, D., 1986. A 40,000 year-old human occupation site at Huon Peninsula, Papua New Guinea. Nature 324, 453 – 455.

Guthrie, R.D. 1983. Osseous projectile points: biological considerations affecting raw material selection and design among Paleolithic and Paleoindian peoples. In: Clutton-Brock, J. and Grigson, C. (Eds.) British Archaeological Reports International Series 163 Animals and Archaeology 1: Hunters and Their Prey, pp. 273-294.

Harrnstein, R.J., 1972. Nature as Nurture: Behaviorism and the Instinct Doctrine. Behavior 1, 23–52.

Hayden, B., 1997. Sticks and stones and ground edge axes: the Upper Palaeolithic in Southeastern Asia? In: J. Allen, J. Jones (Eds.), Sunda and Sahul, Academic Press, London, pp. 31-72.

Henshilwood, C.S., Marean, C.W., 2003. The origin of modern human behaviour, critique of the models and their test implications. Curr. Anthrop. 44, 627-651.

Henshilwood, C. S. Sealy, J. C., 1997. Bone artefacts from the Middle Stone Age at Blombos Cave, southern Cape, South Africa. Curr. Anthrop. 38, 890–895.

Henshilwood, C.S., D'Errico, F., Marean, C., Milo, R.G., Yates, R., 2001. An early bone tool industry from the Middle Stone Age at Blombos Cave, South Africa: implications for the origins of modern human behaviour, symbolism and language. J. Hum. Evol. 41, 631-678.

Hooijer, D.A., 1965. Note on *Coryphomys Buhleri* Schaub, a gigantic murine rodent from Timor. Israel J. Zool. 14, 128-133.

Hooijer, D.A., 1971. A giant land tortoise, *Geochelone atlas* (Falconer & Caytley), from the Pleistocene of Timor. I and II Proc. Koninklijk Nederland. Akad. Wetenschappen Ser. B, 74, 504-525.

Hughes, I., 1977. New Guinea Stone Age Trade. Terra Australis 3, ANU Press, Canberra.

Indriati, E., Swisher, C.C. III, Lepre, C., Quinn, R.L., Suriyanto, R.A., Hascaryo, A.T., Grün, R., Feibel, C.S., Pobiner, B.L., Aubert, M., Lees, W., Antón, S.C., 2011. The Age of the 20 Meter Solo River Terrace, Java, Indonesia and the Survival of *Homo erectus* in Asia. PLoS ONE 6, e21562. doi:10.1371/journal.pone.0021562.

Johnson, E., 1985. Current developments in bone technology. Adv. Archaeol. Method Theory 8, 157-235.

Julien, M., 1982. Les harpons magdaléniens, Paris, CNRS (Suppléments à Gallia Préhistoire, 17), 299 pp.

Keeley, L.H., 1982. Hafting and Retooling: Effects on the Archaeological Record. Am. Antiquity, 47, 798-809.

Klein, R., 2009. The Human Career. 3rd edition. Chicago University Press, Chicago.

Knecht, H., 1993. Early Upper Paleolithic approaches to bone and antler projectile technology. Archeol. Pap. Amer. Anthropol. Assoc. 4, 33–47.

Knecht, H., 1997. Projectile points of bone, antler and stone: experimental explorations of manufacture and use. In: Knecht, H. (Ed.) Projectile Technology, Plenum, New York, pp. 191–212.

Lampert, R.J., 1966. An excavation at Durras North, New South Wales. Archaeol. Phys. Anthropol. Oceania 1, 83-118.

Lampert, R.J., 1971. Burrill Lake and Currarong. Terra Australis 1, Canberra: Department of Prehistory, Research School of Pacific Studies, The Australian National University.

Langley, M.C., Clarkson, C., Ulm, S., 2011. From small holes to grand narratives: the impact of taphonomy and sample size on the modernity debate in Australia and New Guinea. J. Hum. Evol. 61, 197-208.

Legrand, A., & Sidéra, I. 2007. Methods, means, and results when studying European bone industries. Bones as Tools: Current Methods and Interpretations in Worked Bone Studies. Oxford: BAR International Series, 1622, 2007-67.

Lombard, M., 2004. Distribution patterns of organic residues on middle stone age points from Sibudu Cave, Kwazulu-natal, South Africa. S. Afr. Archaeol. Bull. 59, 37-44.

Lombard, M., 2005. Evidence of hunting and hafting during the Middle Stone Age at Sibidu Cave, KwaZulu-Natal, South Africa: a multianalytical approach. J. Hum. Evol . 48, 279–300.

Mazza, P.P.A., Martini, F., Sala, B., Magi, M., Colombini, M.P., Giachi, G., Landucci, F., Lemorini, C., Modugno, F., Ribechini, E., 2006. A new Palaeolithic discovery: tar-hafted stone tools in a European Mid-Pleistocene bone-bearing bed. J. Archaeol. Sci. 33, 1310-1318.

McBrearty, S., Brooks, A.S., 2000. The revolution that wasn't: a new interpretation of the origin of modern human behaviour. J. Hum. Evol. 39, 453-563.

Mithen, S., 1996. The prehistory of the mind: a search for the origin of art, science and religion. Thames & Hudson, London.

Moore, M.W., Sutikna, T., Jatmiko, Morwood, M., Brumm, A., 2009. Continuities in stone flaking technology at Liang Bua, Flores, Indonesia. J. Hum. Evol. 57, 503-526.

Morwood, M.J., Seojono, R.P., Roberts, R.G., Sutikna, T., Turney, C.S.M., Westaway, K.E., Rink, W.J., Zhao, J.-X., van den Bergh, G.D., Due, R.A., Hobbs, D.R., Moore, M.W., Bird, M.I., Fifield, L.K., 2004. Archaeology and age of a new hominin from Flores in Eastern Indonesia. Nature 431, 1087-91.

Movius Jr., H.L., 1948. The Lower Palaeolithic cultures of southern and eastern Asia. Trans. Am. Phil. Soc. 38, 329-420.

Naiman, J., 2004. How Societies Work: Class, power, and change in a Canadian context, 3rd ed., Thomson Publishers. Toronto.

O'Connor, S., 2007. New evidence from East Timor contributes to our understanding of earliest modern human colonisation east of the Sunda Shelf. Antiquity 81, 523–535.

O'Connor, S., Aplin, K.P., 2007. A matter of balance: an overview of Pleistocene occupation history and the impact of the Last Glacial Phase in East Timor and the Aru Islands, eastern Indonesia. Archaeol. Oceania 42, 82-90.

O'Connor, S., Ono, R., Clarkson, C., 2011. Pelagic fishing at 42,000 BP and the maritime skills of modern humans. Science 334, 117-1121.

O'Connor, S., Spriggs, M., Veth, P., 2002. Excavation at Lene Hara establishes occupation in East Timor at least 30,000 – 35,000 years on: results of recent fieldwork. Antiquity 76, 45-50.

O'Connor, S., Spriggs, M., Veth, P., 2003 Direct dating of shell beads from Lene Hara Cave, East Timor. Aust. Archaeol. 55, 18-21.

O'Connor, S., Barham, A. Spriggs, M.,' Veth, V.' Aplin, K.P., St. Pierre, E., 2010. Cave archaeology and sampling issues in the Tropics: A case study from Lene Hara Cave, a 42,000 year old occupation site in East Timor, Island Southeast Asia. Aust. Archaeol. 71, 29-40.

Palter, J.L., 1977. Design and construction of Australian spear-thrower projectiles and hand-thrown spears. Archaeol. Phys. Anthropol. Oceania 12, 161-172.

Pasveer, J.M., 2004. The Djief Hunters:26,000 Years of Rainforest Exploitation on the Bird's Head of Papua, Indonesia. Mod. Quat. Res. Southeast Asia 17. A.A. Balkema, Lisse.

Pasveer, J.M., Bellwood, P., 2004. Prehistoric bone artefacts from the northern Moluccas, Indonesia. In: Keates, S. G., Pasveer, J.M. (Eds.), Quaternary Research in Indonesia, Mod. Quat. Res. Southeast Asia 18. A.A. Balkema, Leiden, pp. 301-59.

Perera, N., Kourampas, N., Simpson, I. A. Deraniyagala, S. U., Bulbeck, D., Kamminga, J., Perera, J., Fuller, D. Q., Szabó, K., Oliveira, N. V., 2011. People of the ancient rainforest: Late Pleistocene foragers at the Batadomba-lena rockshelter, Sri Lanka. J. Hum. Evol. 61, 254-269.

Pétillon J.M., 2005. Tir experimental de pointes à base fourchue en bois de renne. In:V.Dujardin (Ed.), Industrie osseuse et parures du Solutréen au Magdalénien en Europe. Société préhistorique française (mémoires34), Paris: 243-256.

Pétillon, J.-M., 2008. What are these barbs for? Preliminary study on the function of the Upper Magdalenian barbed weapon tips. In: J.-M. Pétillon, M.-H. Dias-Meirinho, P. Cattelain, M. Honegger, C. Normand, N. Valdeyron (coord.), Projectile weapon elements from the Upper Palaeolithic to the Neolithic (Proceedings of session C83, XVth World Congress UISPP, Lisbon, September 4-9, 2006), *Palethnologie*, 1, p. 66 - 97.

Pétillon, J.M., Ducasse, S., 2012. From flakes to grooves: A technical shift in antlerworking during the last glacial maximum in southwest France. J. Hum. Evol. 62, 435-465.

Phillipson, D.W., 1977. Lowasera. Azania 12, 1-32.

Pokines, J.T., 1998. Experimental replication and use of Cantabrian lower Magdalenian antler projectile points. J. Archaeol. Sci. 25, 875-886.

Pokines, J.T., Krupa, M., 1997. Self-barbed antler spearpoints and evidence of fishing in the late Upper Paleolithic of Cantabrian Spain. In: Knecht, H. (Ed.), Projectile Technology. Plenum Press (Interdisciplinary contributions to archaeology), New York, pp. 241-262.

Rabbett, R.J., Piper, P.J., 2012. The Emergence of Bone Technologies at the End of the Pleistocene in Southeast Asia: Regional and Evolutionary Implications. Cambridge Archaeol. J. 22, 37-56.

Read, D., van der Leeuw, S., 2008. Biology is only part of the story ... Phil. Trans. R. Soc. B 363, 1959-1968.

Rosell, J., Blasco, R., Campeny, G., Díez, J.C., Alcalde, R. A., Menéndez, L., Arsuaga, J.L., Bermúdez de Castro, J.M., Carbonell, E., 2011. Bone as a technological raw material at the Gran Dolina site (Sierra de Atapuerca, Burgos, Spain). J. Hum. Evol. 61, 125-31.

Rots, V., 2013. Insights into early Middle Palaeolithic tool use and hafting in Western Europe. The functional analysis of level IIa of the early Middle Palaeolithic site of *Biache-Saint-Vaast* (France). J. Archaeol. Sci. 40, 497-506.

Rots, V., Van Peer, P., Vermeersch, P.M., 2011. Aspects of tool production, use, and hafting in Palaeolithic assemblages from Northeast Africa. J. Hum. Evol. 60, 637-664.

Sillitoe, P. 2008. Made in Niugini. Technology in the Highlands of Papua New Guinea. British Museum, London.

Swisher, C.C. III, Rink, W.J., Antón, S.C., Schwarcz, H.P., Curtis, G., Widiasmoro, A.S., 1996. Latest *Homo erectus*, in Java: potential contemporaneity with *Homo sapiens* in Southeast Asia. Science 274, 1870–1874.

Spriggs, M., O'Connor, S., Veth, P., 2003. Vestiges of early pre-agricultural economy in the landscape of East Timor: recent research. In: Kallen, A., Karlstrom, A (Eds.), Fishbones and Glittering Emblems: Proceedings from the EurASEEA Sigtuna Conference, Museum of Far Eastern Antiquities, Stockholm, pp. 49-58.

Tartar, E., 2012. The recognition of a new type of bone tools in Early Aurignacian assemblages: implications for understanding the appearance of osseous technology in Europe. J. Archaeol. Sci. 39, 2348-2360.

Tartar, E. and White, R., 2013. The manufacture of Aurignacian split-based points: an experimental challenge. J. Archaeol. Sci. 40, 2723-2745.

Tejero, J. M., Christensen, M., Bodu, P. 2012. Red deer antler technology and early modern humans in Southeast Europe: an experimental study. J. Archaeol. Sci. 39, 332-346.

Thieme, H., 1997. Lower Paleolithic hunting spears from Germany. Nature 385, 769–771.

Thompson, T.J.U., Islam, M., Piduru, K., Marcel, A., 2011. An investigation into the internal and external variables acting on crystallinity index using Fourier Transform Infrared Spectroscopy on unaltered and burned bone. Palaeogeog., Palaeoclimatol., Palaeoecol. 299, 168–174.

Van Heekeren, H.R., 1972. The Stone Age of Indonesia. Rev. ed. Martinus Nijhoff, The Hague.

Villa, P., d'Errico, F., 2001. Bone and ivory points in the Lower and Middle Palaeolithic of Europe. J. Hum. Evol. 41, 69-112.

Wadley, L., Hodgskiss, T., Grant, M., 2009. Implications for complex cognition from the hafting of tools with compound adhesives in the Middle Stone Age, South Africa. Proc. Natl Acad. Sci. 106, 9590-9594.

Waguespack, N.M., Surovell, T.A., Denoyer, A., Dallow, A., Savage, A., Hyneman, J., Tapster, D., 2009. Making a point: wood- *versus* stone-tipped projectiles. Antiquity 83, 786–800.

Webb, C., Allen, J., 1990. A functional analysis of bone tools from two sites in southwest Tasmania. Archaeol. Oceania 25, 75-78.

West, J.A., Louys, J., 2007. Differentiating bamboo from stone tool cut marks in the zooarchaeological record, with a discussion on the use of bamboo knives. J. Archaeol. Sci. 34, 512-518.

White, C., 1967. Early stone axes in Arnhem Land. Antiquity 41, 149-52.

Yellen, J.E., Brooks, A.S., Cornelissen, E., Mehlman, M.J., Stewart, K., 1995. A Middle Stone Age worked bone industry from Katanda, Upper Semliki, Zaire. Science 268, 553-556.

Yellen, J.E., 1998. Barbed Bone Points: Tradition and continuity in Saharan and Sub-Saharan Africa. The Afr. Archaeol. Rev. 15, 173-198.

Zhilin, M.G., 1998. Technology of the manufacture of Mesolithic bone arrowheads on the Upper Volga. Europ. J. Archaeol. 1, 149-176.

Figure captions

Figure 1. Map showing the location of islands and other localities mentioned in the text.

Figure 2. The MK2 bone artefact: a) outer or cortical surface; b) inner or medullary surface. Details of the notches and tang are shown in slightly oblique close-up views. Scale bar = 10 mm.

Figure 3. Microscopic details of the MK2 artefact, illustrating surface modifications and adherent hafting materials. a: diffuse polish and localized patches of mastic near the tip of the tang; b: obliquely oriented striae present on the inner surface of the tang; c: cross-cutting oblique furrows on the lateral margin of the tang, interpreted as the product of pressure from binding cordage. The granular material associated with these features has the appearance of mastic when viewed at higher magnifications; d: rounding and polish on the edges of the notches. Also visible are a number of clear transverse striae that are aligned with the notches. At least some of the material embedded within the vascular canals has the appearance of mastic; e: patches of mastic associated with the lateral notches. Rounding and polish of the notches is also visible; f: higher magnification view of one of the patches of mastic shown on Fig. 3e. The diagnostic feature of cracking is observed in the mastic and a starch grain is present.

Figure 4. A degraded hair shaft fragment retained within a vascular groove on the inner surface of the artefact.

Figure 5. Two possible hafting methods for the MK2 artefact, each consistent with its morphological features and indications of hafting cordage. In both cases, the shape of the project point is conjectural; mastic is not shown but this would have encased the haft to provide extra mechanical support. In a) the point is bound against the side of a shaft, probably bearing a facet or notch to receive the tang. In b) the point is inserted into a split hollow shaft (e.g. a bamboo culm) with the tang probably pushed into a hollow prepared in the nodal tissue. Under this method, to account for cordage marks on the tang, the artefact must have been bound to one side of the split shaft, prior to the external binding to hold the shaft together.

Figure 6. Comparison of the MK2 bone artefact with one of the Katanda bone points (Kt9:7B; redrawn from illustration in Baquedano 2007, p. 97).

TABLE

Table 1: Radiocarbon and calibrated ages from the MK2 test pit. Dates were calibrated using OxCal 4.1.

Excavation Unit	**Lab code**	**C14 Age**	**Cal BP Age 95.4 % OxCal 4.1**	**Material**
SPIT 10	NZA16136	2,450+/-40	2,256 –1,977	marine shell
SPIT 13	OZG537	2,510+/- 50	2,745 –2,366	*Celtis* sp. seed
SPIT 13	OZG538	3,190+/-40	3,134 –2,861	marine shell
SPIT 15	NZA18656	8,966+/-55	9,828 –9,504	marine shell
SPIT 17	NZA17008	10,292+/-60	11,615 –11,157	marine shell
SPIT 25	NZA17009	10,078+/-60	11,208 –10,814	marine shell
SPIT 26	NZA16137	9,650+/-55	10,619 –10,374	marine shell
SPIT 31	OZG899	9,190+/-50	10,161– 9,811	marine shell bead
SPIT 32	OZG897	9,260+/-60	10,220 – 9,894	marine shell bead
SPIT 32	NZA16138	11,173 +/- 55	12,808 –12,561	marine shell
SPIT 36	OZG737	26,690 +/170	31,370 –30,979	*Celtis* sp. seed
SPIT 41	NZA16177	31,060+/-130	36,268 –34,649	marine shell

SPIT 47	OZF785	32,200+/-300	36,866 –35,285	marine shell

Figure
Click here to download high resolution image

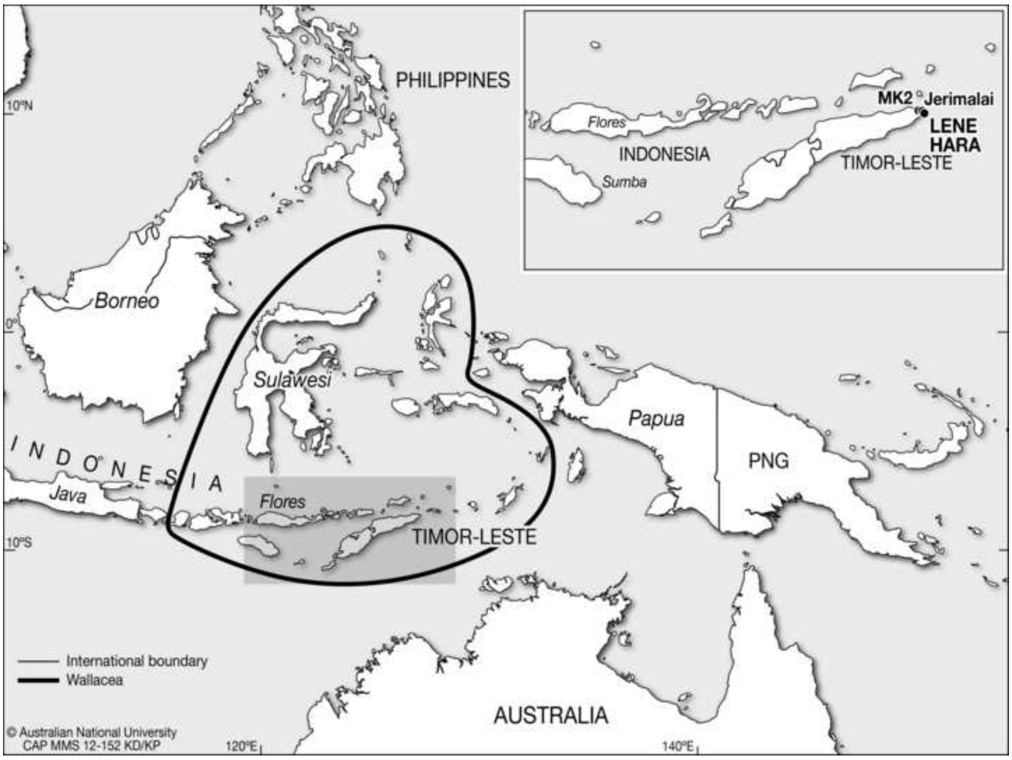

Figure
Click here to download high resolution image

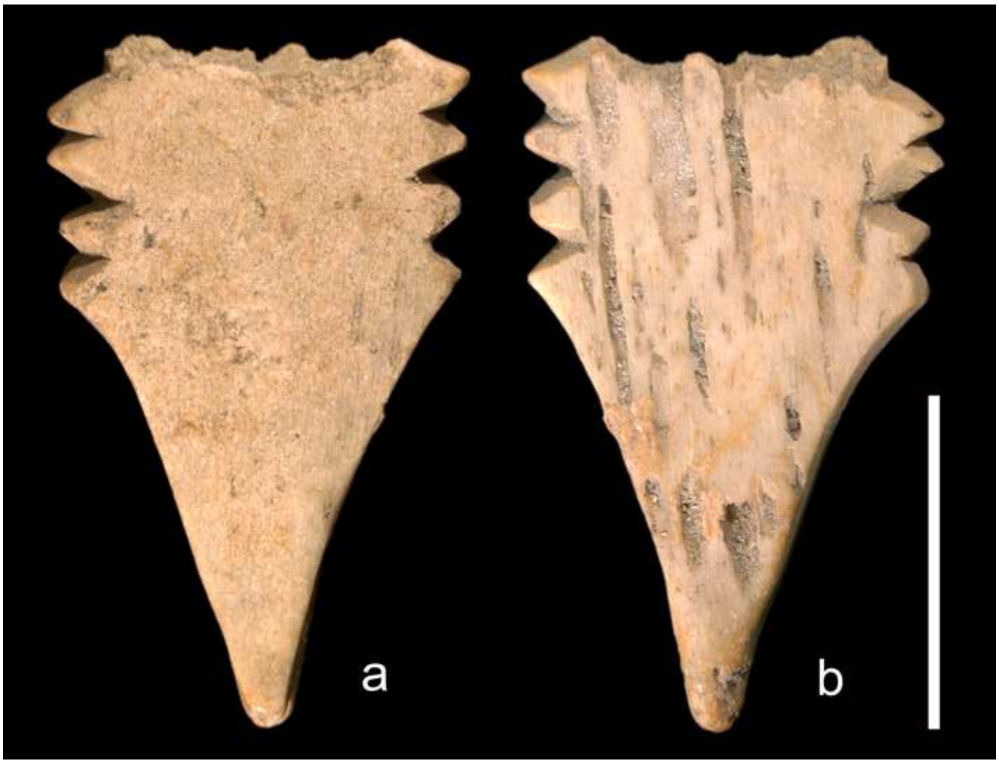

Figure
Click here to download high resolution image

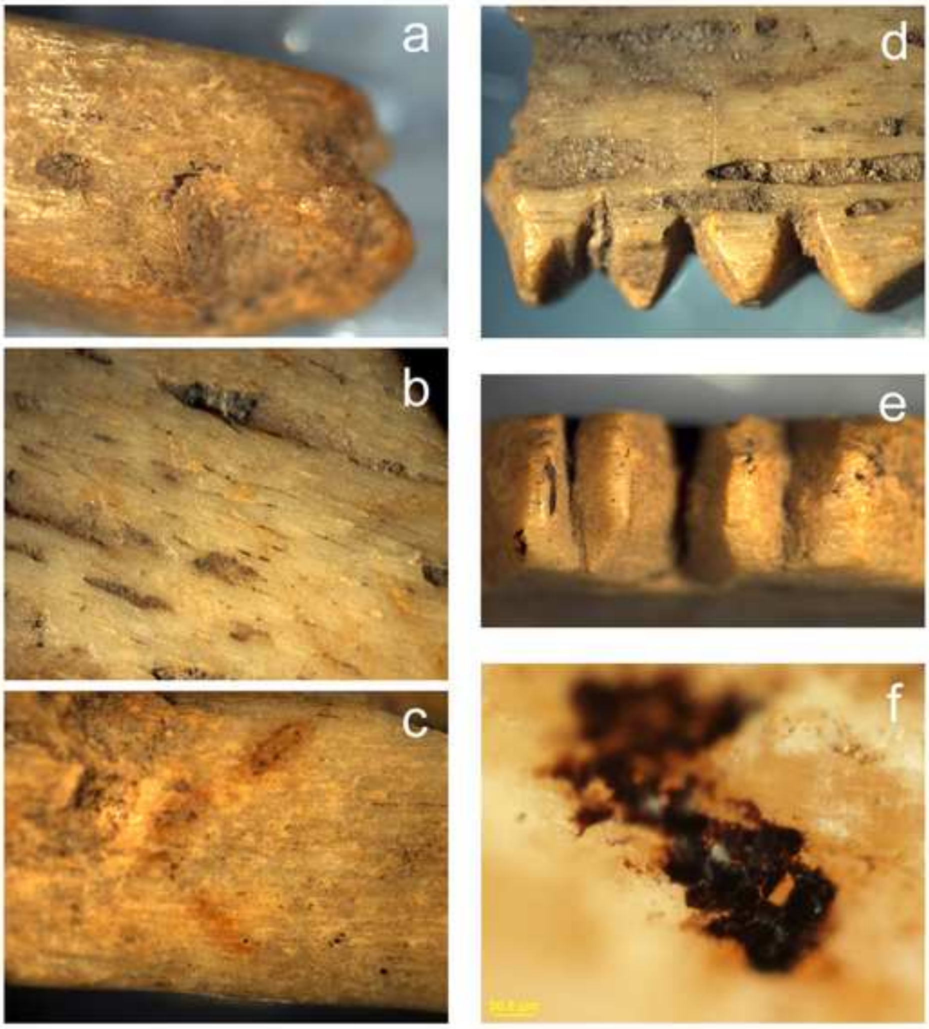

Figure
Click here to download high resolution image

Figure
Click here to download high resolution image

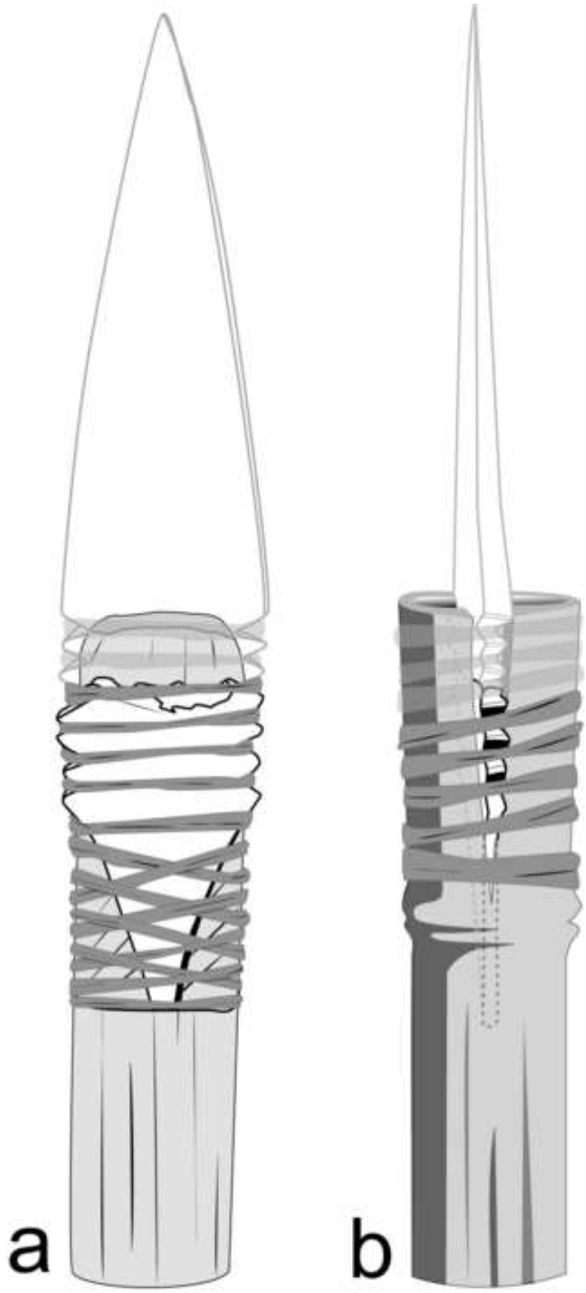

Figure
Click here to download high resolution image